



31 May 2023

# Design and manufacturing of complex shaped service interface panel with sheet moulding compound -process

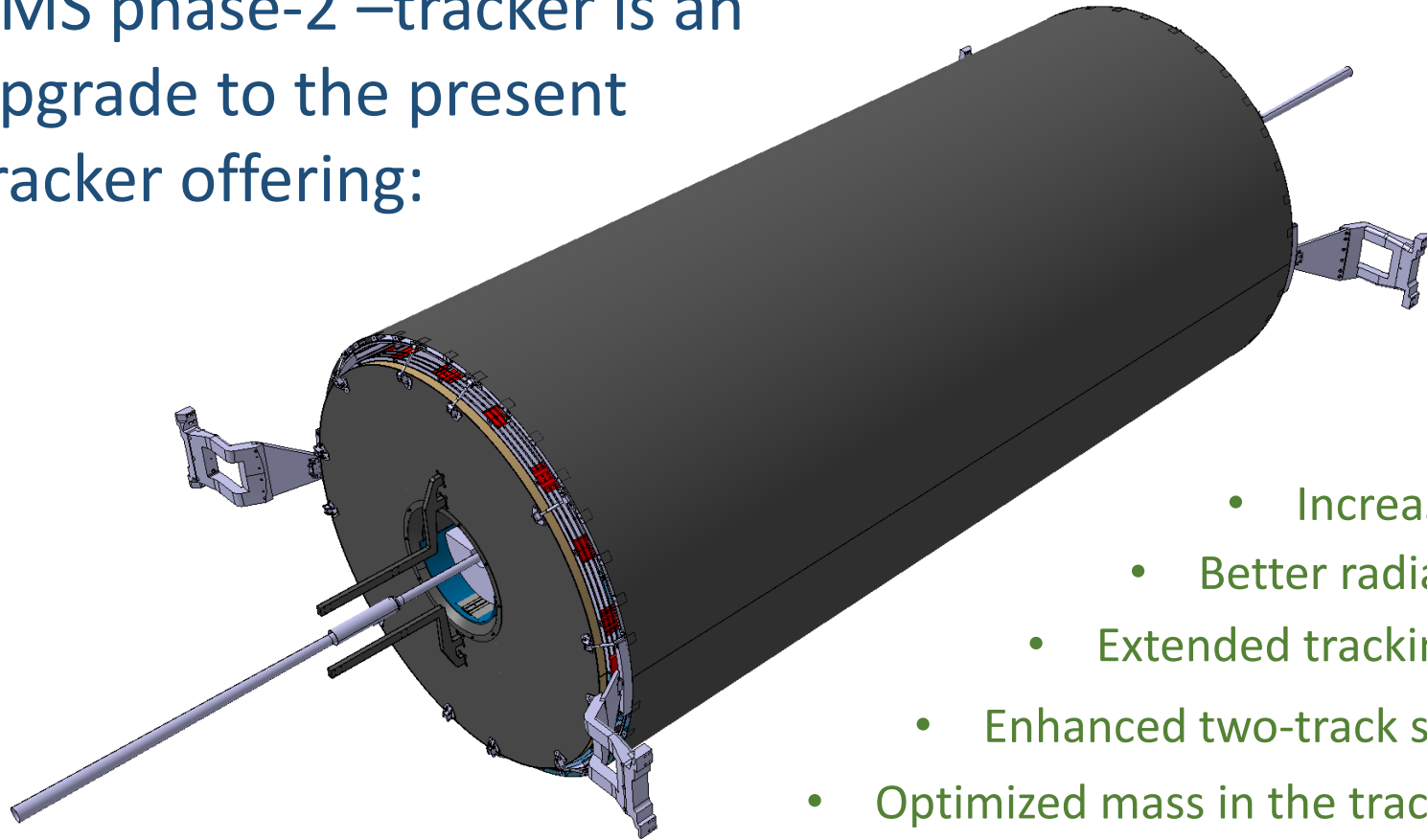
Mikko Barinoff, Francois Boyer, Francisco Perez, Remus Vrancianu

on behalf of the Tracker-group



## CMS phase-2 tracker

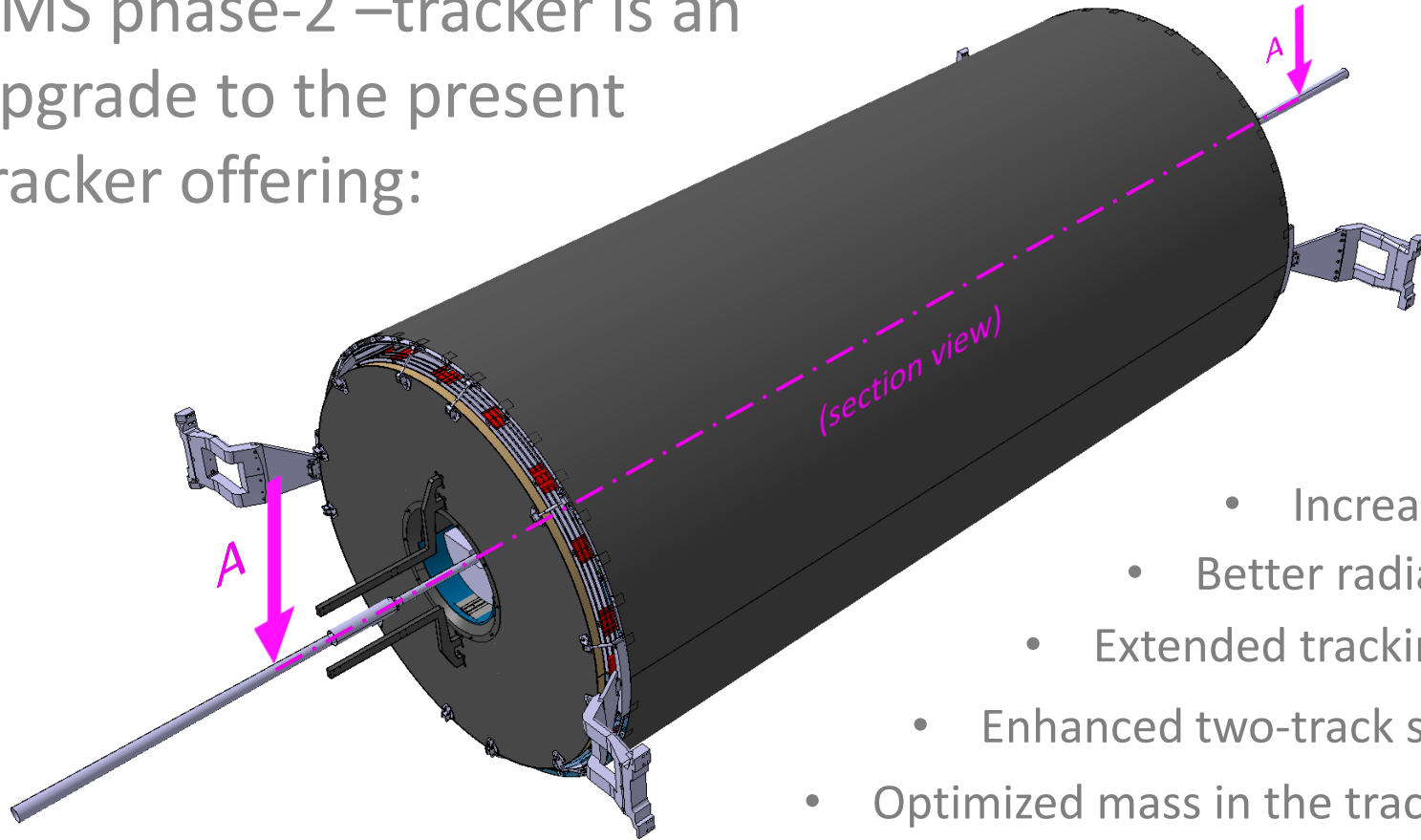
CMS phase-2 –tracker is an upgrade to the present tracker offering:



- Increased granularity
- Better radiation resistance
- Extended tracking capability
- Enhanced two-track separation
- Optimized mass in the tracking volume
- Reliable pattern recognition
- Contribution to the level-1 trigger

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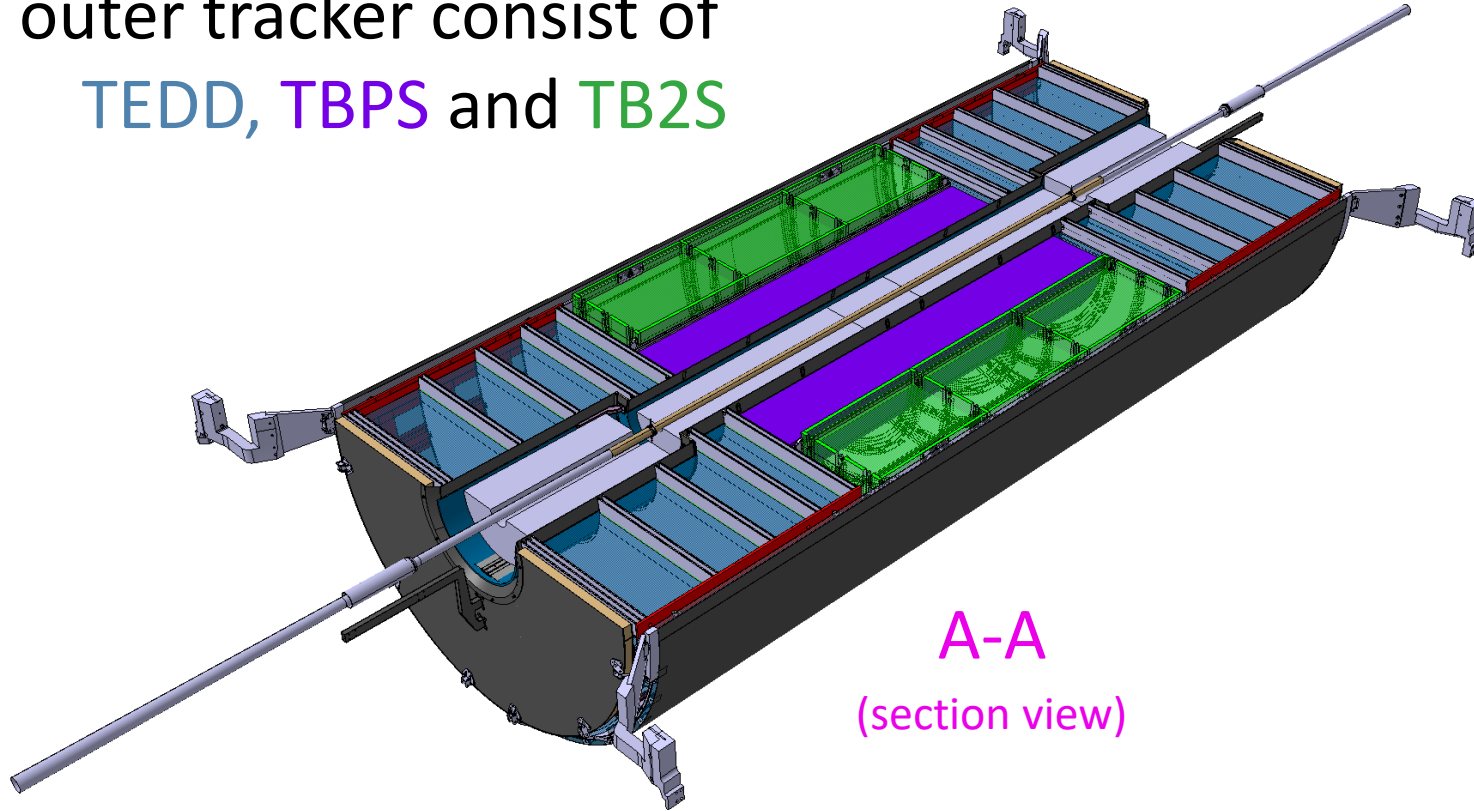


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# CMS phase-2 tracker

The outer tracker consist of  
TEDD, TBPS and TB2S

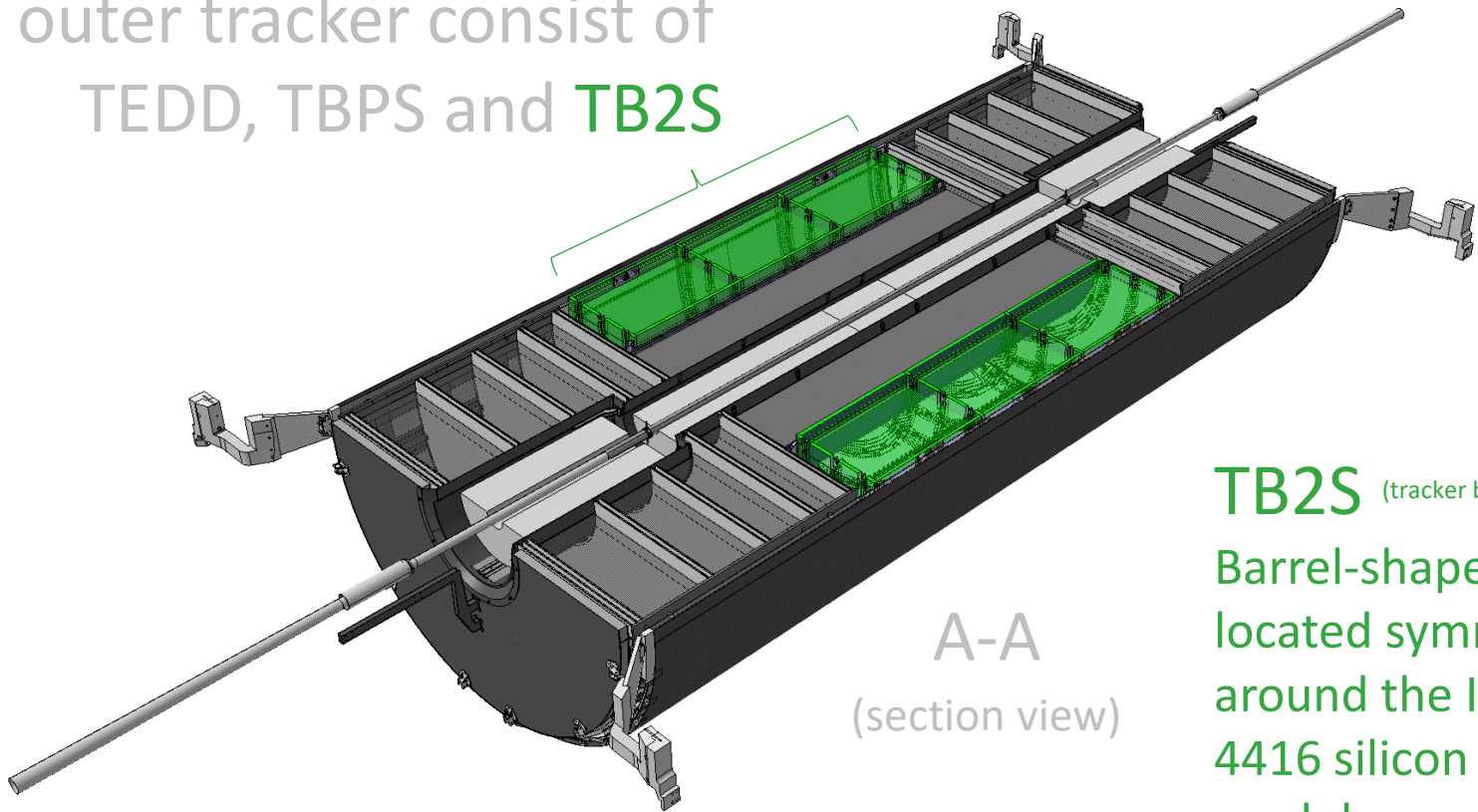


A-A  
(section view)



# CMS phase-2 tracker

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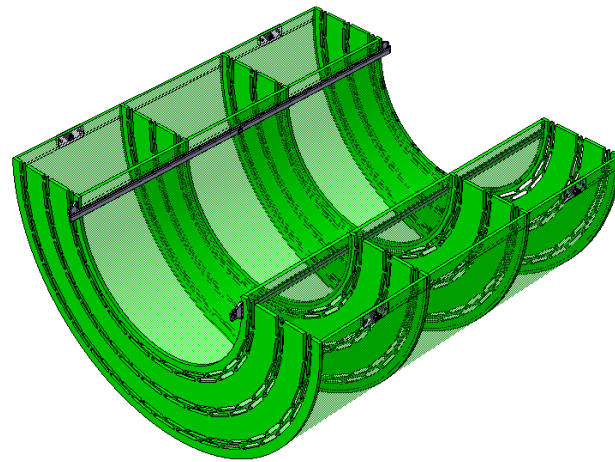


A-A  
(section view)

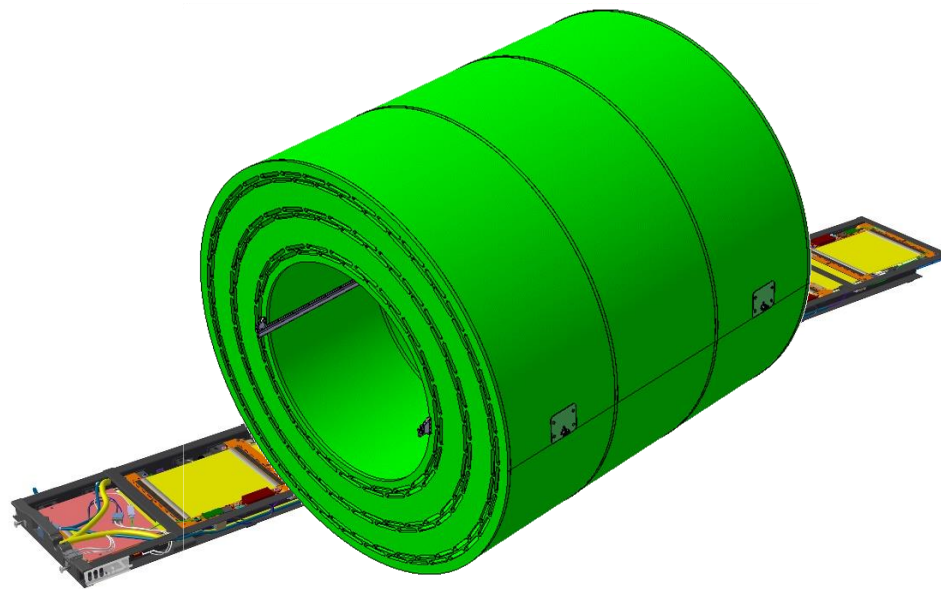
**TB2S** (tracker barrel with 2S-modules)  
Barrel-shaped section  
located symmetrically  
around the IP, hosting  
4416 silicon detector  
modules on three layers



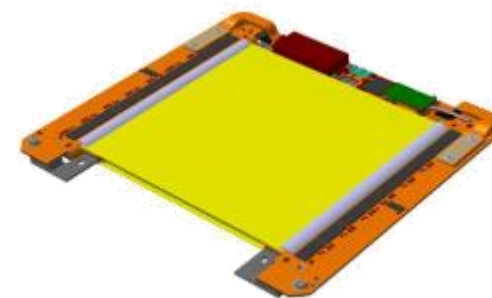
# TB2S



Wheel



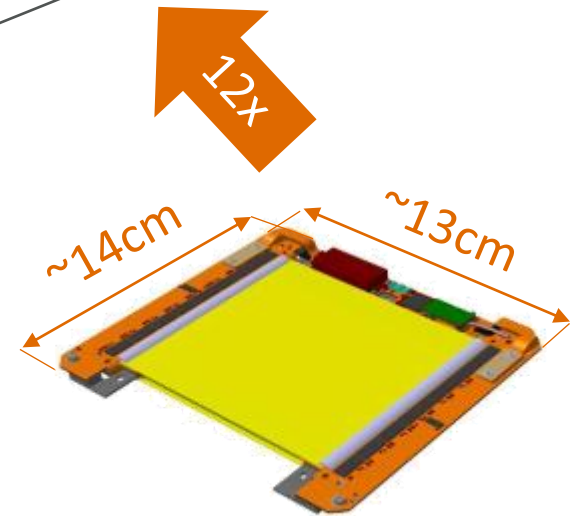
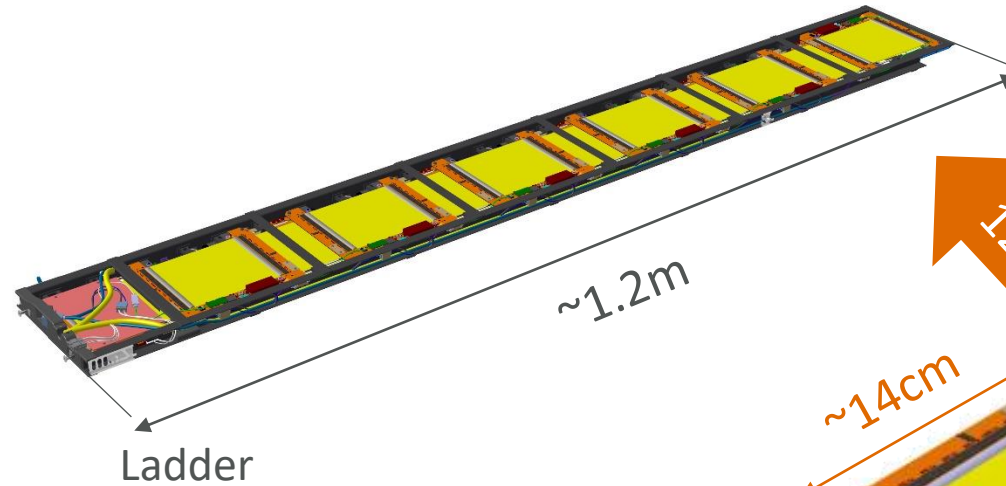
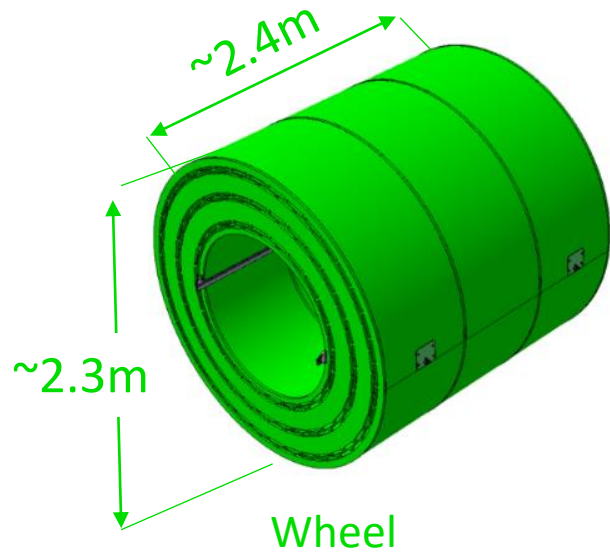
Ladder



2S-type detector module, with two strip sensors back-to-back



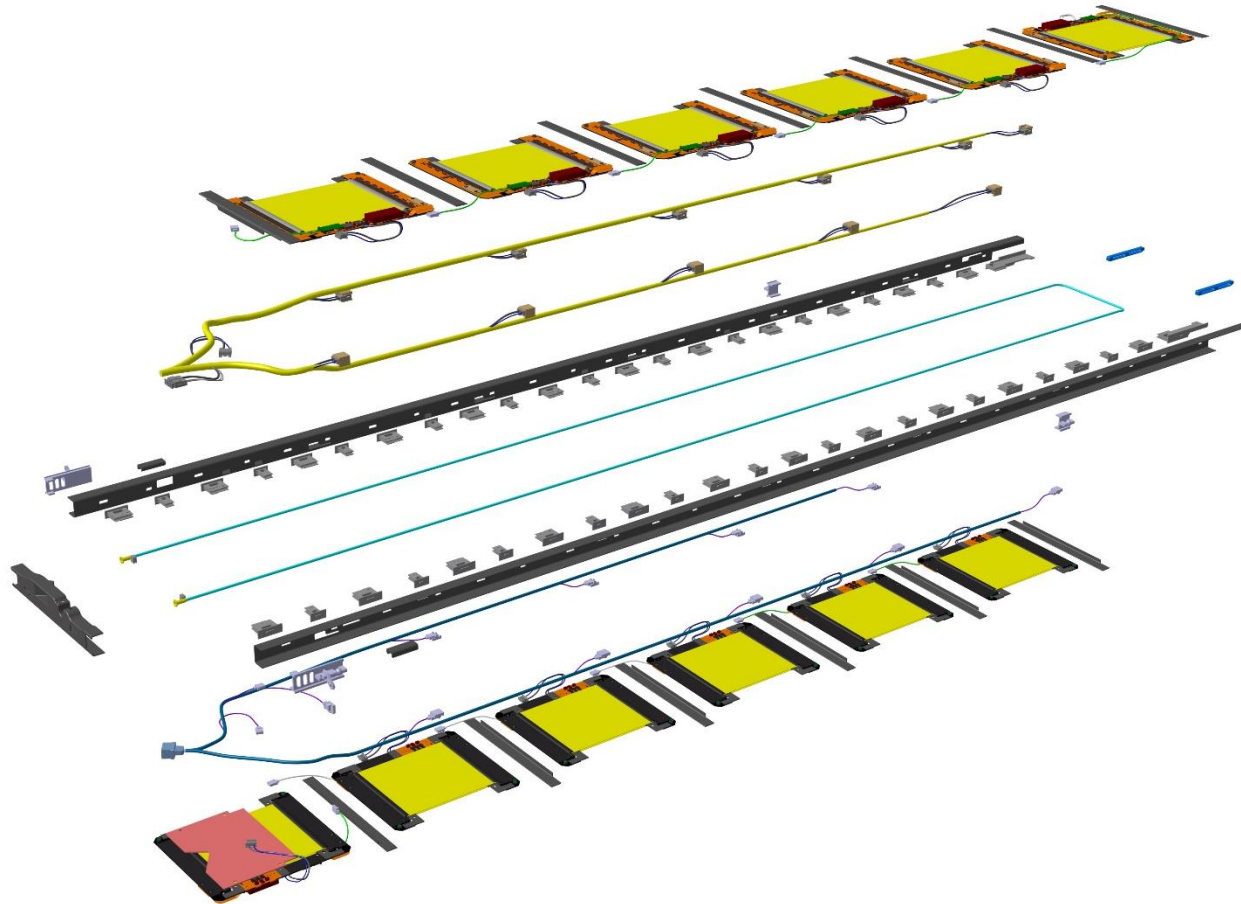
# TB2S



2S-type detector module, with two strip sensors back-to-back

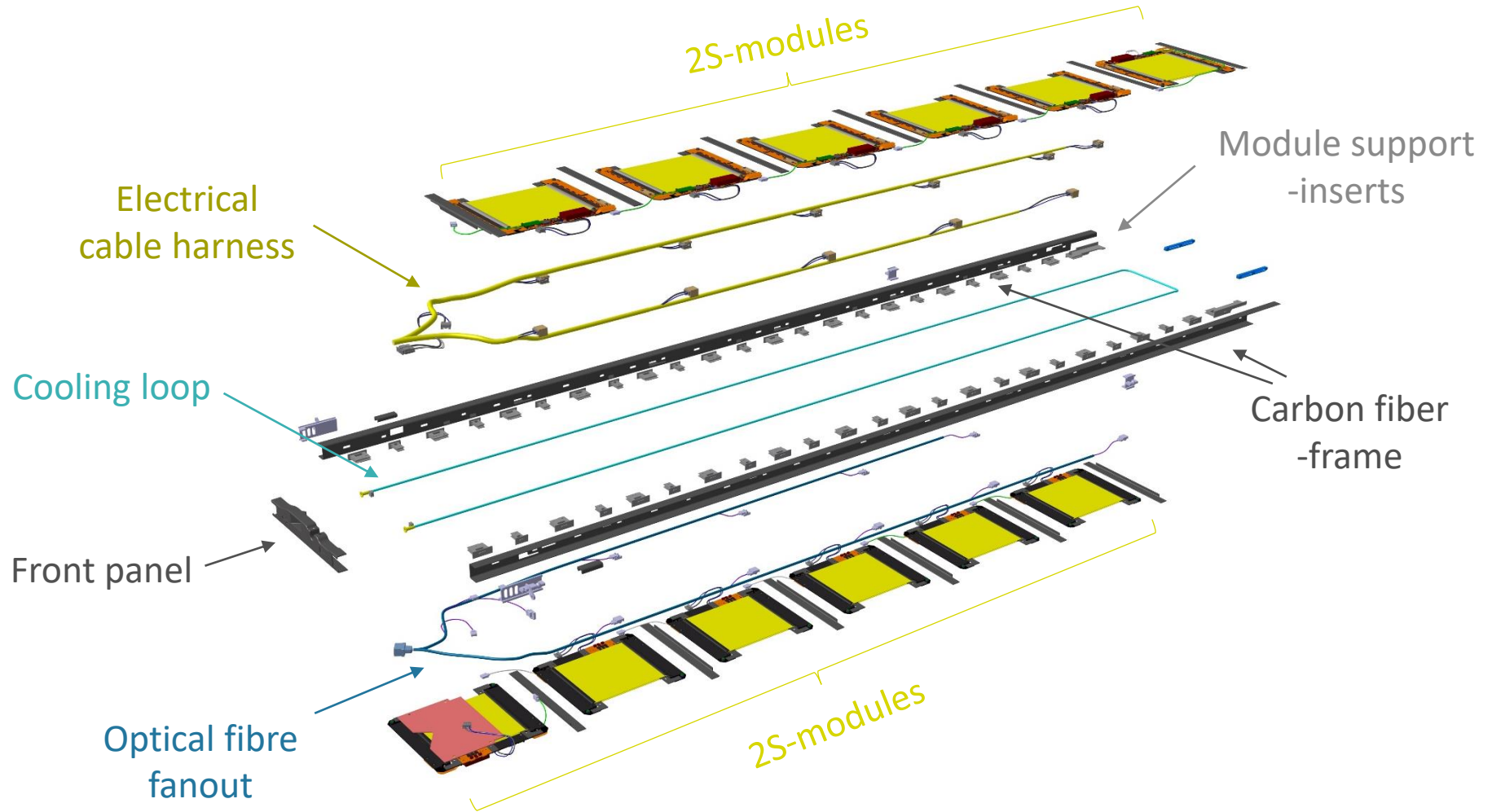


# TB2S ladder



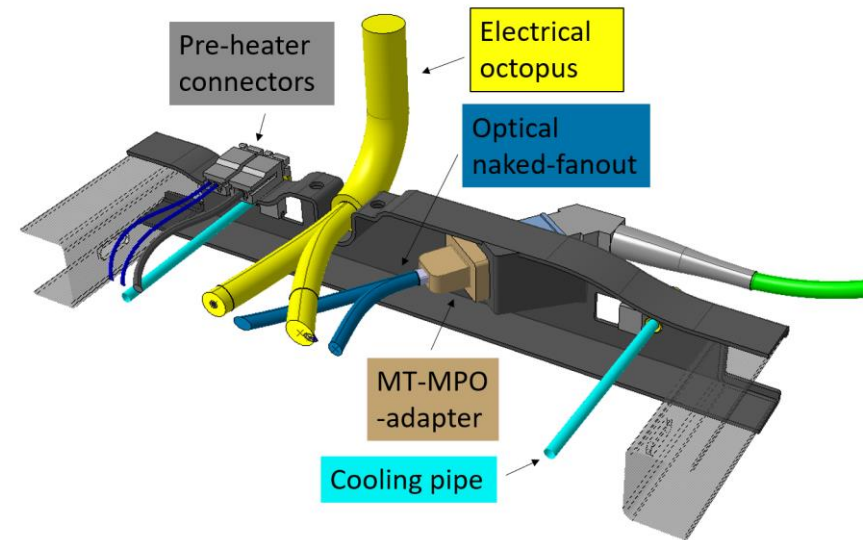
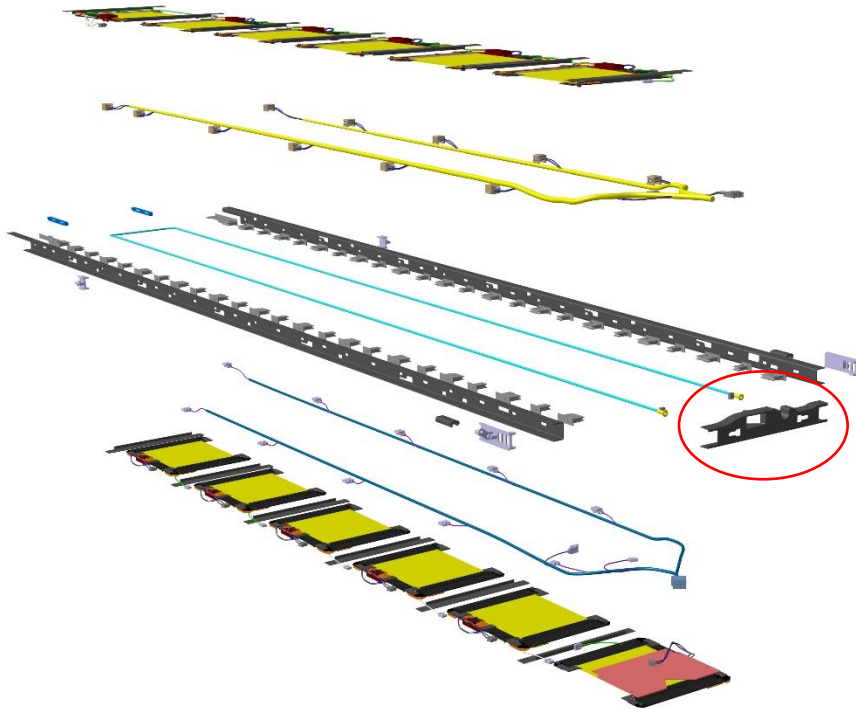


# TB2S ladder



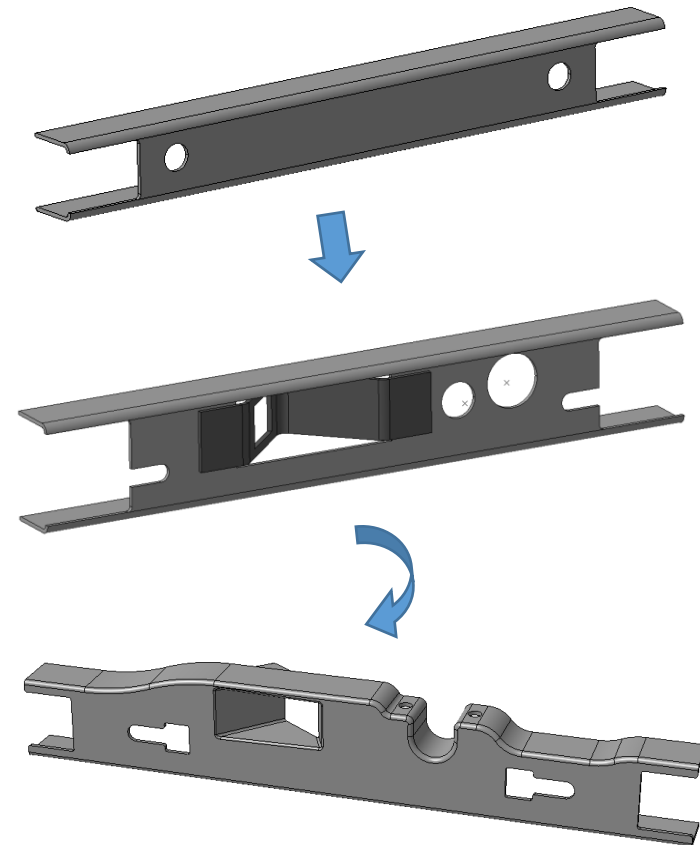
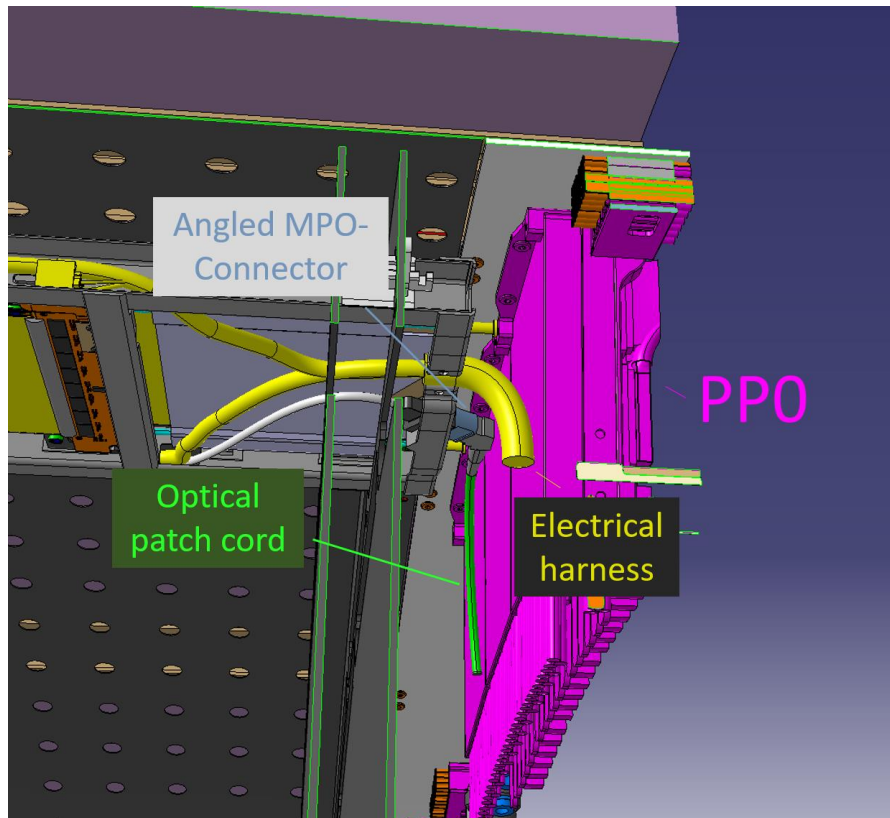
# Front panel design

- The front panel acts as an interface for all the ladder services
  - Electrical cable harness, optical patch-cord, cooling pipe connections, pre-heater connectors



## Front panel design

- The carbon-fibre C-profile used elsewhere in the Ladder needed to be replaced by a more complex part due constraints set by the connections and the very limited space available





## Material choice

- Strong and stiff material, adapted for making a complex 3D geometry was needed
- The choice was to use a fibre-reinforced moulding compound. They are available as bulk (BMC) and sheet moulding compounds (SMC)
  - The compound consists of:
    - Thermosetting resin (e.g. polyester, vinyl ester, polyurethane, or epoxy) + inorganic filler
    - Fiber reinforcement (typically glass- or carbon fiber, ~6-50mm length)
  - Worked with compression moulding
    - Heat and pressure applied coincidentally in a metal mould to attain desired shape

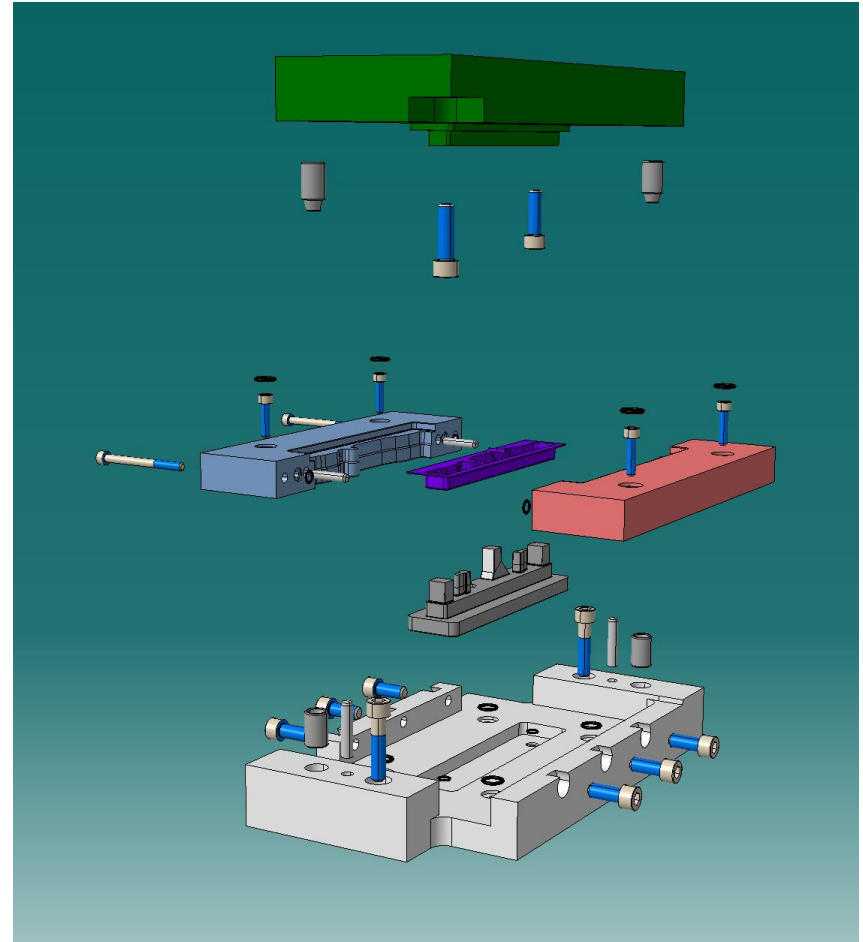


<https://smcbmc-europe.org/publications.php>



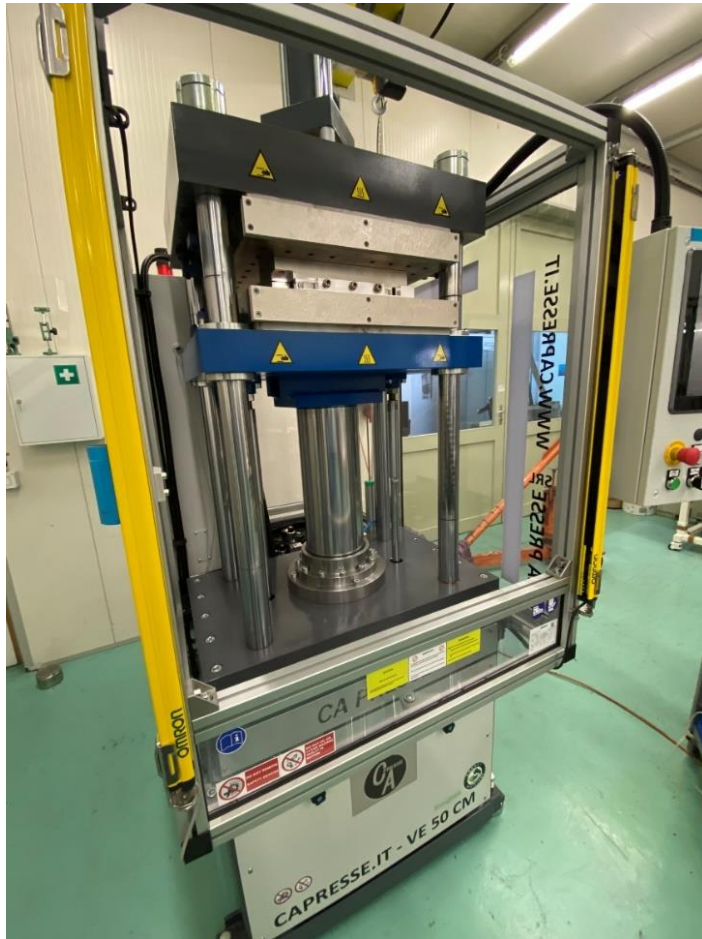
# The compression mould

- Designed a compression mould, that forms a volumetric cavity giving the shape for the final piece (purple)
  - A lot of effort put already in the design phase for mould usability and de-moulding



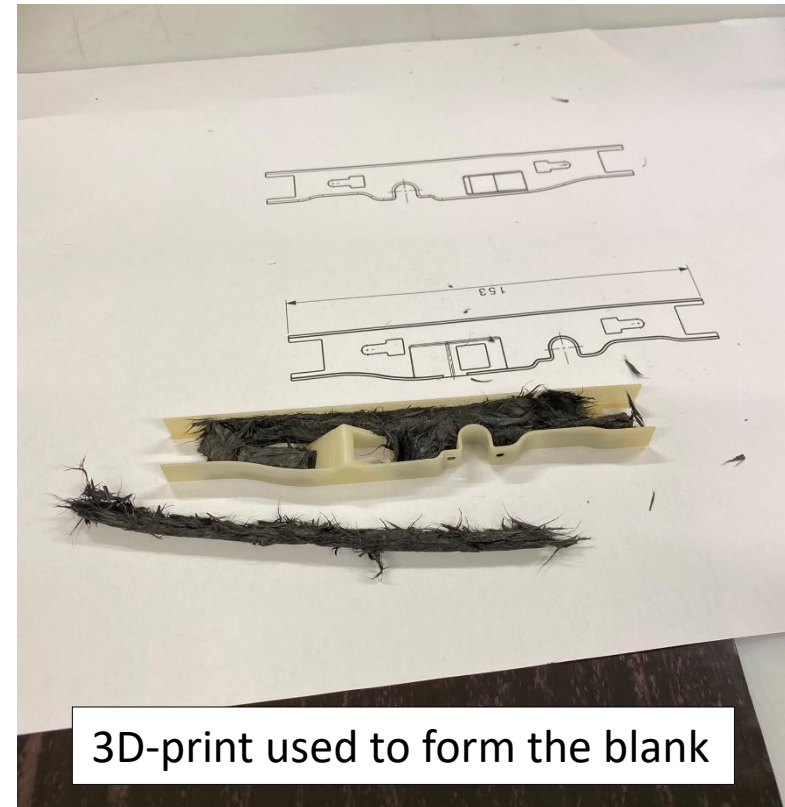
# The hot press machine

- Two heated beds, the bottom bed is moving along the hydraulic cylinder



## Step 1: Setting up the material

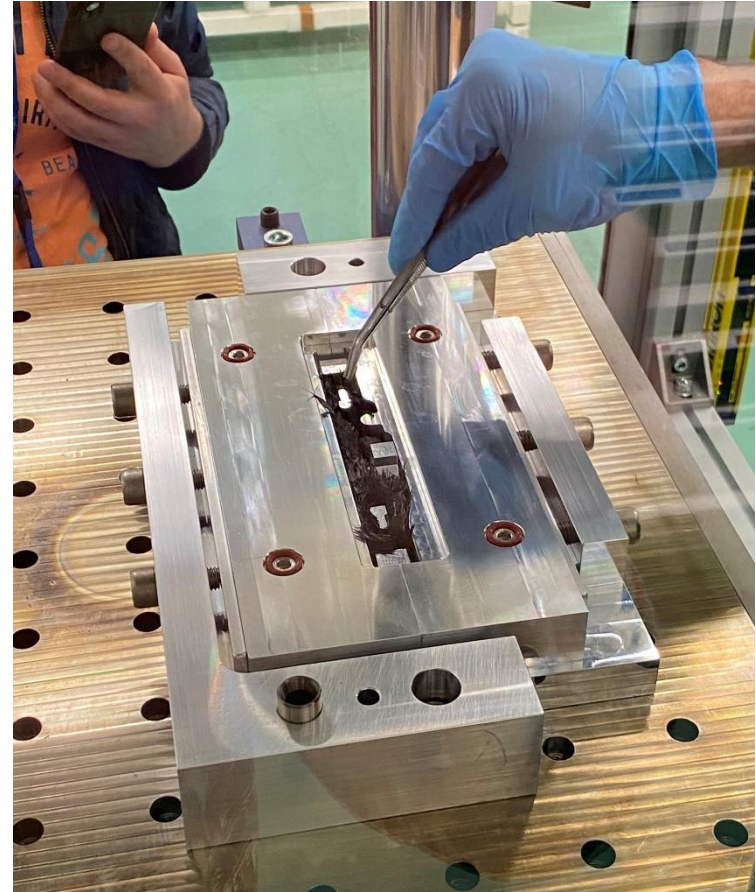
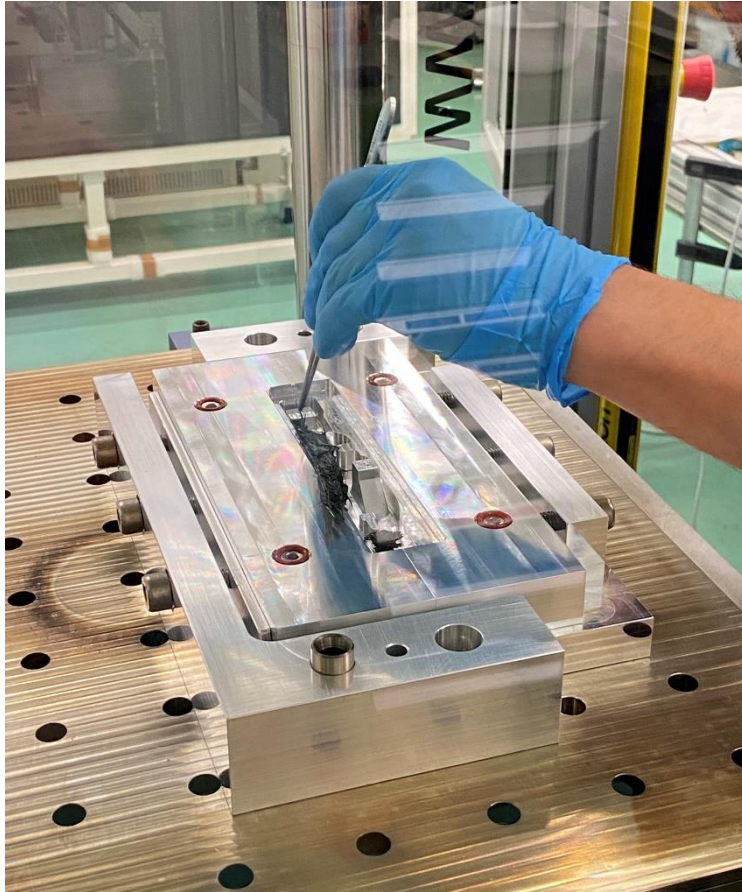
- Started with a carbon fiber – vinyl ester -BMC-material
- Filling the mould with exactly the right amount of material is crucial





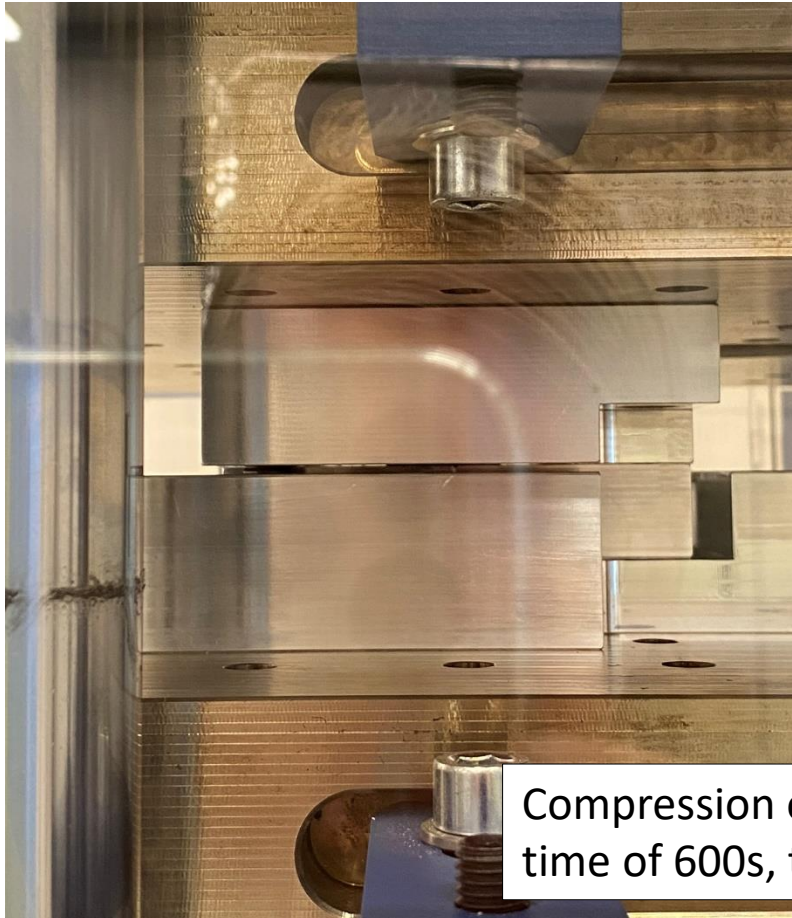
## Step 1: Setting up the material

- Filling the pre-heated mould has to be done quickly, because the material starts polymerizing already after 15 seconds



## Step 2: Compression cycle

- Filling is ideal when the mould is not quite closing entirely, and the pressure remains fully on the material

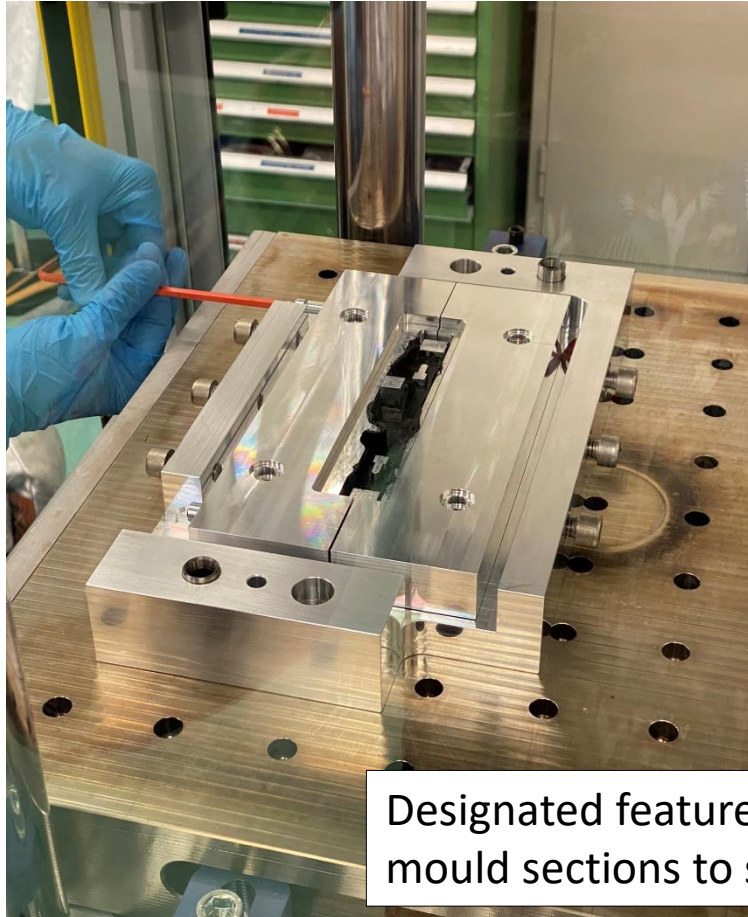


Compression of 3t applied, cycle time of 600s, temperature at 150°C



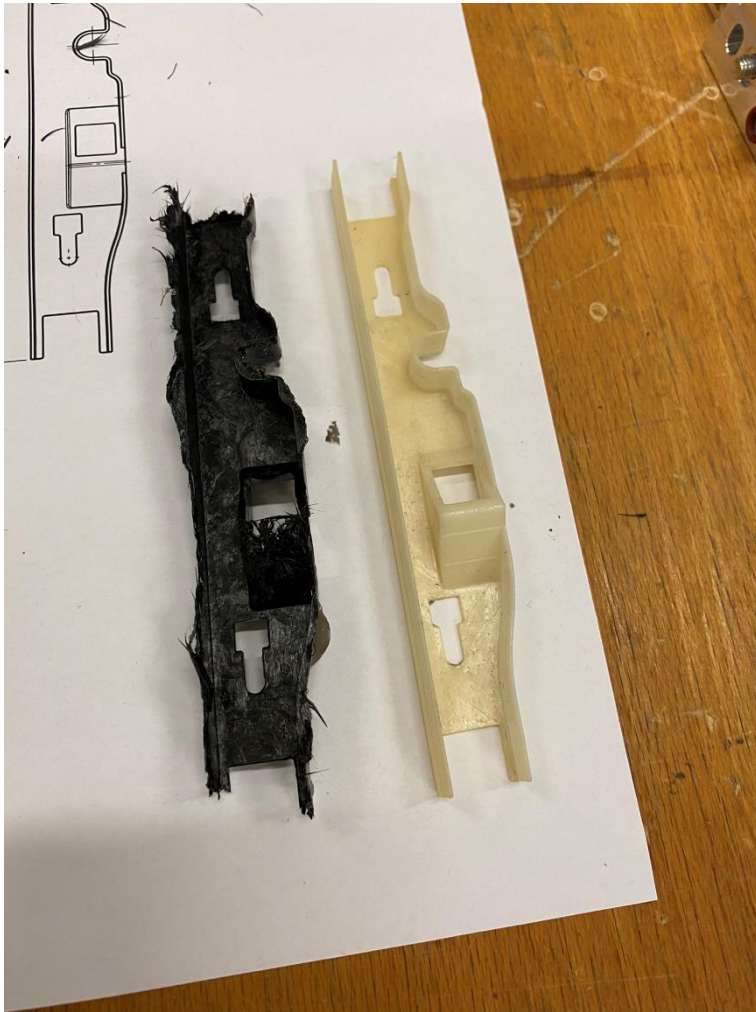
## Step 3: De-moulding

- De-moulding was a concern initially, but the pieces came out quite nicely
  - Hot surfaces complicate the practical work



Designated features were used to force the mould sections to separate from each other

# Iterations



1<sup>st</sup> trial: too little material



2<sup>nd</sup> trial: too much material & improper closing

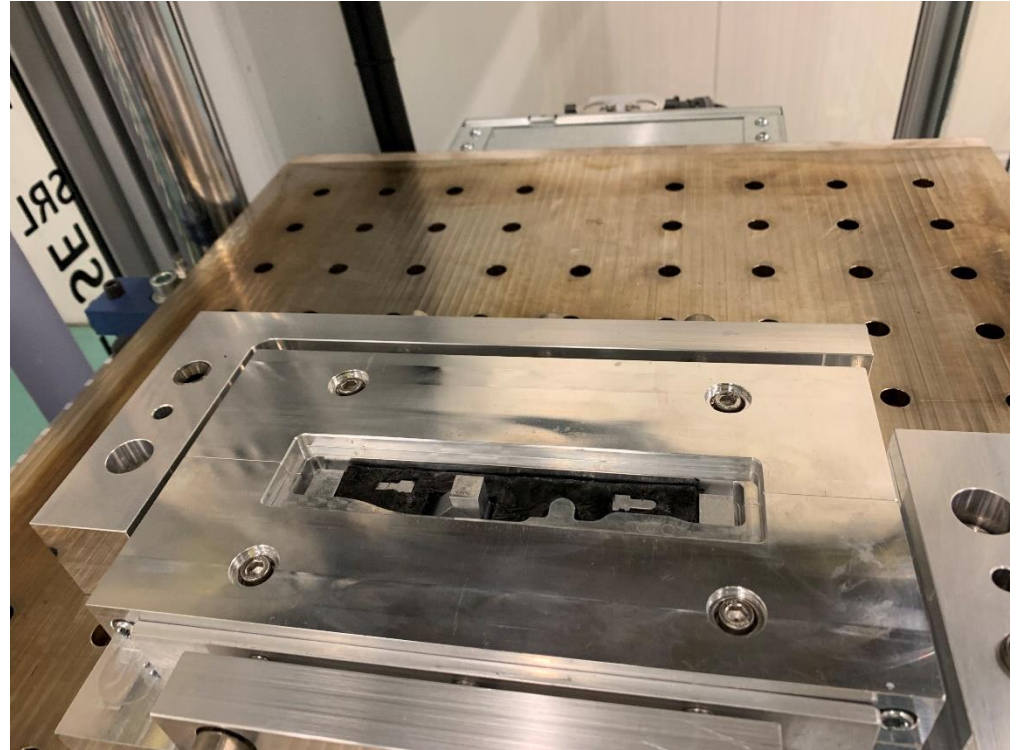


# Iterations



4<sup>th</sup> trial: Already quite good, the flow wasn't so efficient though due to outdated material

## Iterations



5<sup>th</sup> trial: Switch to fresh SMC material, the SMC sheet was pre-cut according to the mould outline, making the material installation much easier

## Iterations



5<sup>th</sup> trial: A really big improvement, the material flows well and fills the mould cavity almost perfectly



# Iterations

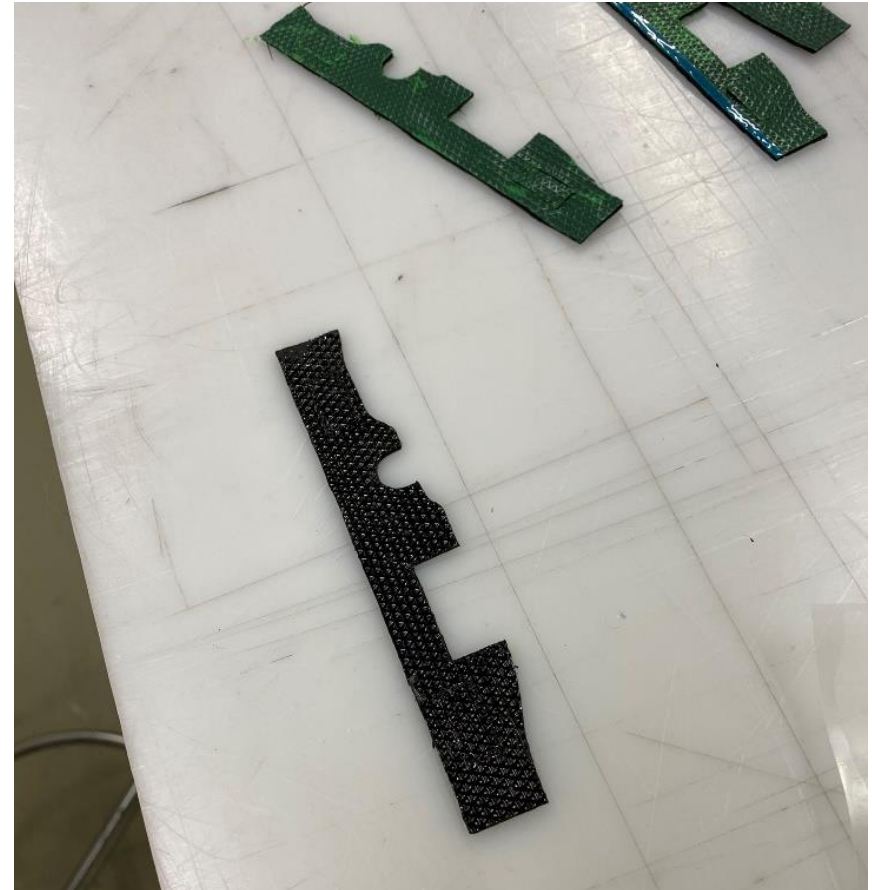


8<sup>th</sup> trial: Success!

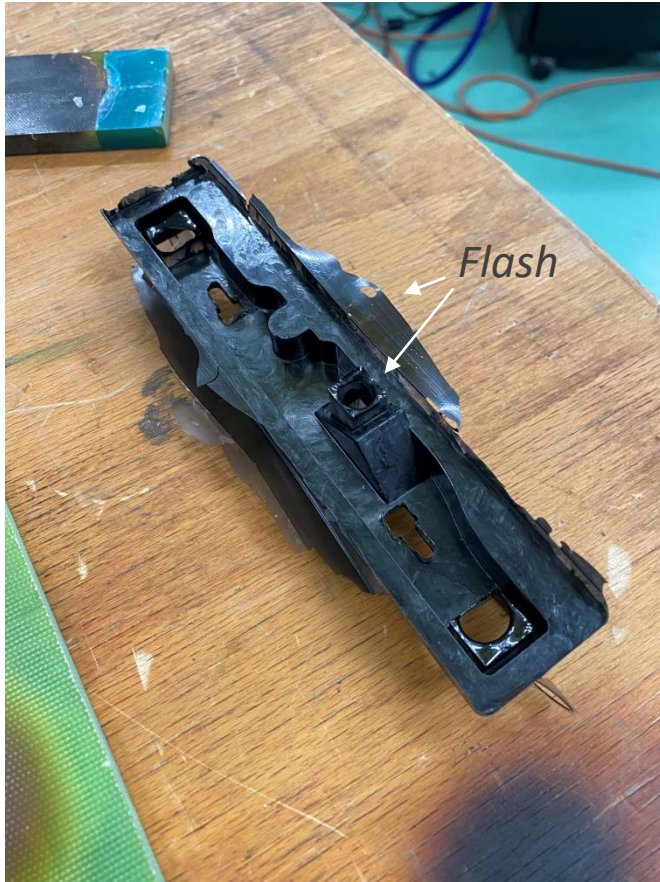


- Finally an epoxy-based material was tested:
  - Radiation resistant (in TB2S's dose criteria)
  - Requires a pre-cure step (90sec) in the compression cycle

Material parameters:	
Fiber tow tex.	12K
Fiber length	25mm
Nominal fiber content	50%
Areal weight	1500g/m <sup>2</sup>
Typical cure temperature	135-145°C
Typical cure time	90sec/mm
Blank size	15.8g



# Iterations

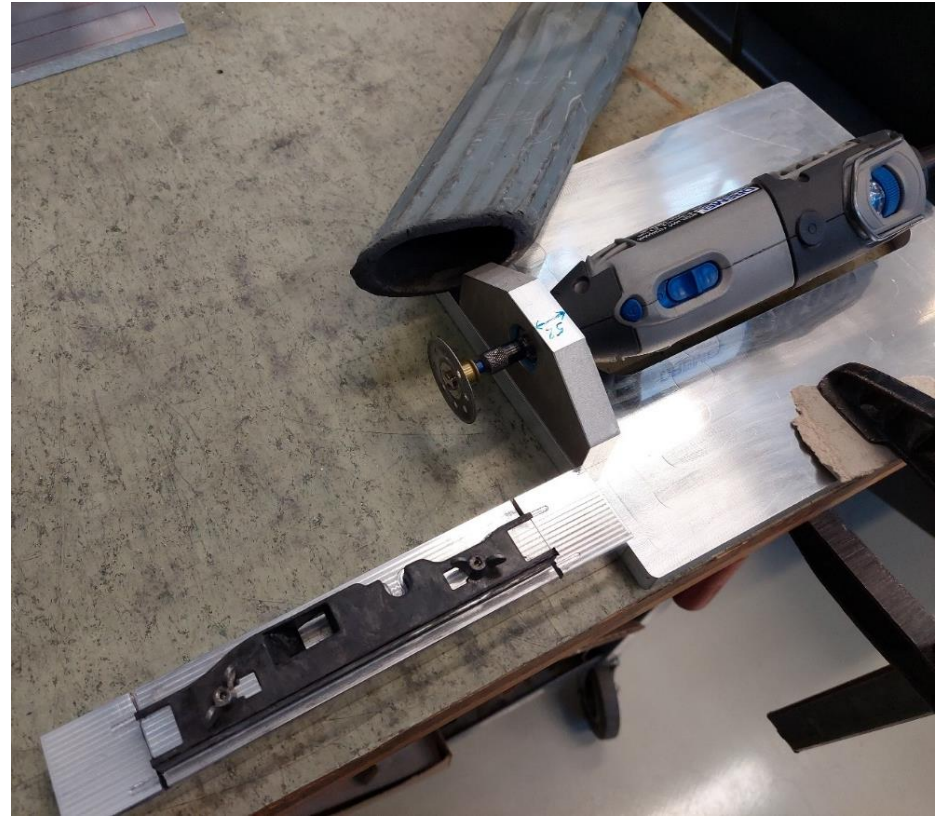
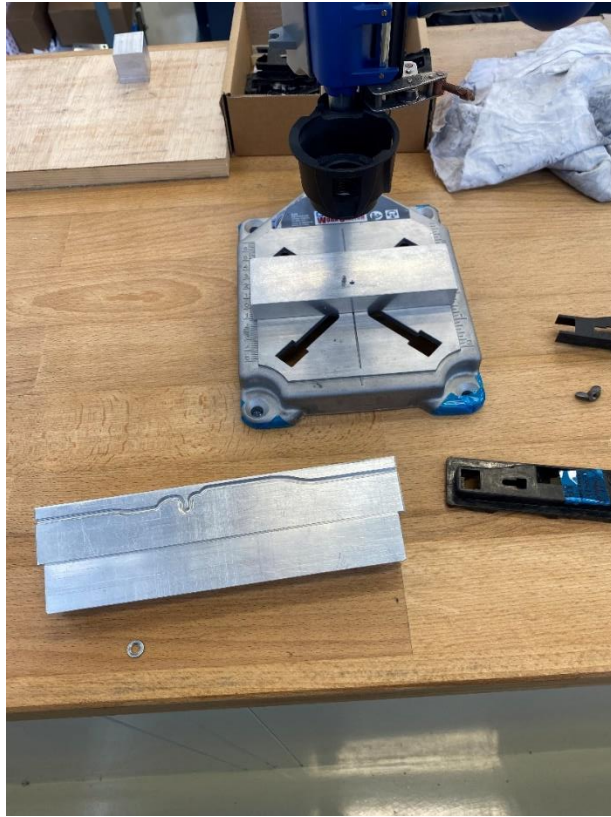


9<sup>th</sup> trial: Equally good end result, slightly more flash creation

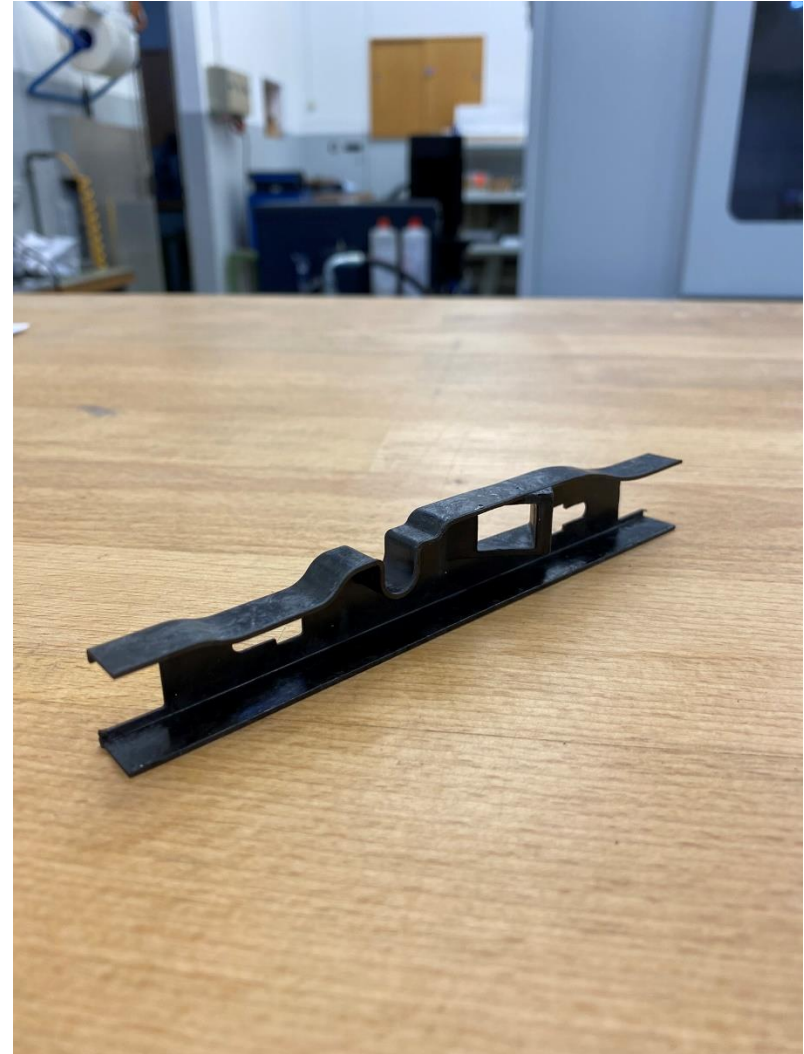


## Step 4: Afterworks

- The moulded piece is placed on a jig, and the excess material on the part edges is cut off with a rotary blade tool



## Finished piece







## Finished piece



## Finished piece



Fitting to the longitudinal C-profiles



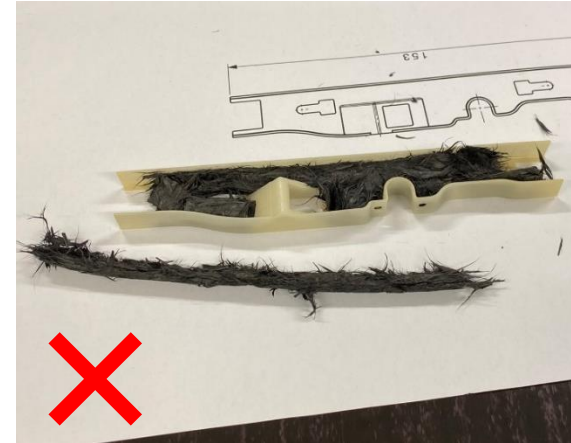
## Conclusion

- The SMC/BMC –process proved out to suit well for the manufacture of the TB2S Front Panel
  - Geometrically complicated part in strong and stiff material, made in a process that is well suited for series production
- The process was rehearsed with a prototype series, and finetuning of the material, blank shape and machine parameters was done
  - Epoxy-based SMC proved out to be the best choice for the use-case
- Some design improvements to the mould were recognized to increase productivity
  - Top mould was sectioned to allow maintenance, and the bottom mould geometry was optimized to ease installation of the material



## Conclusion

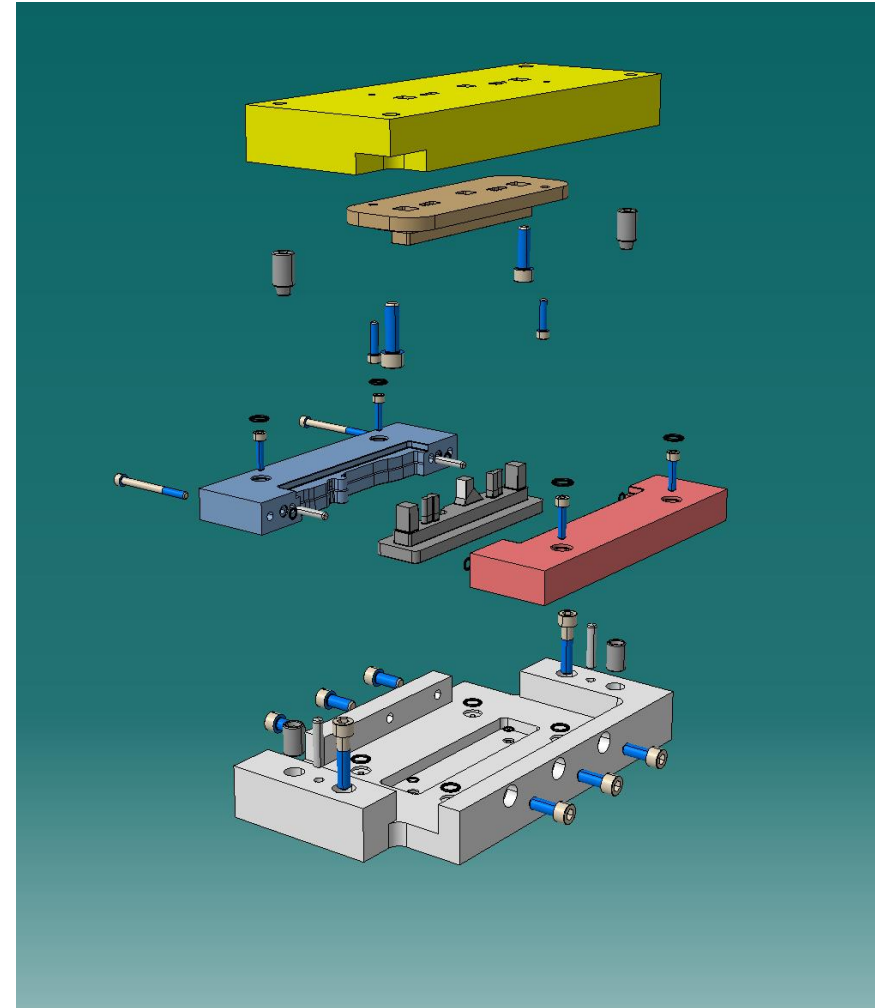
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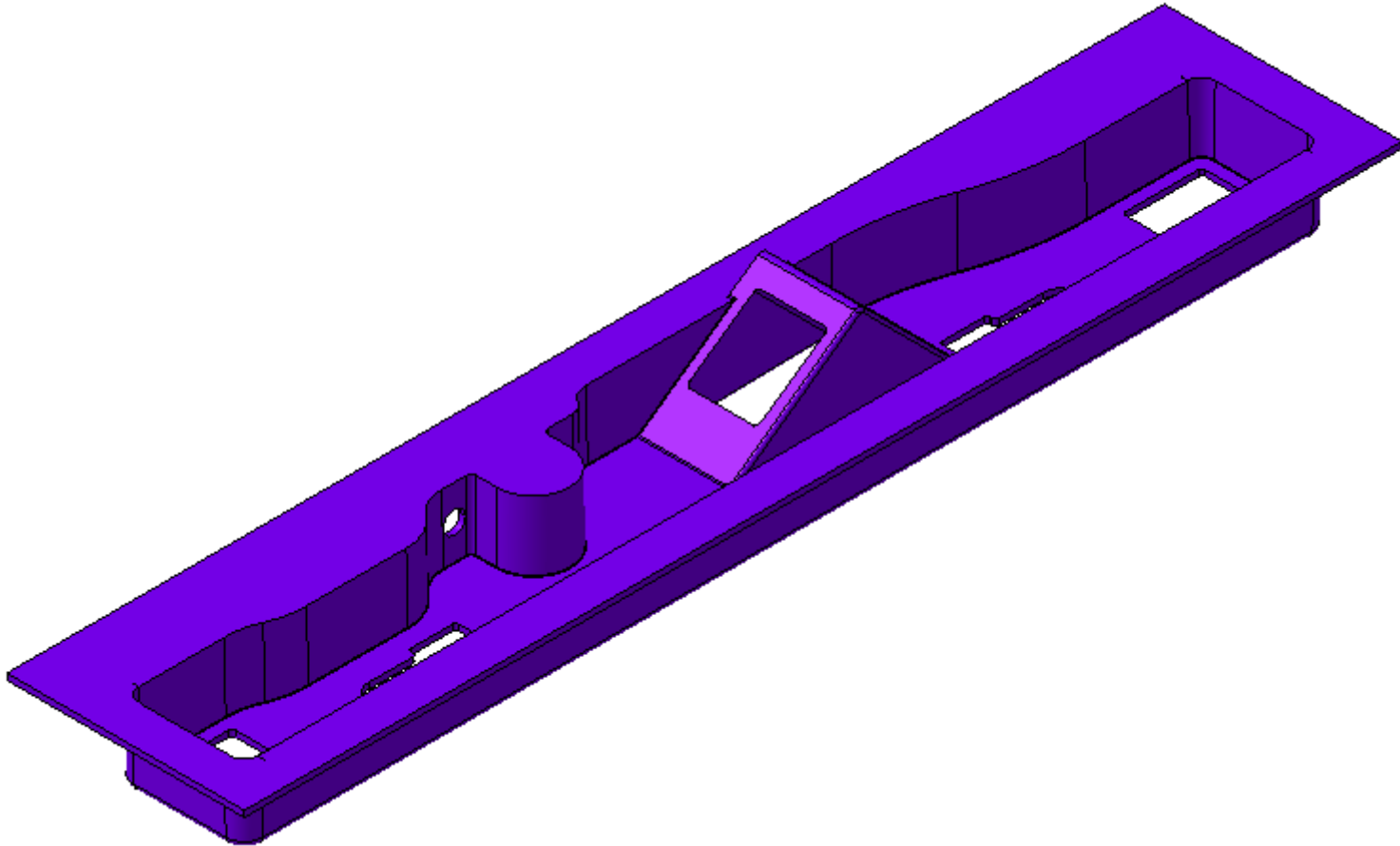




# Spares



## The moulded piece (with the brim)

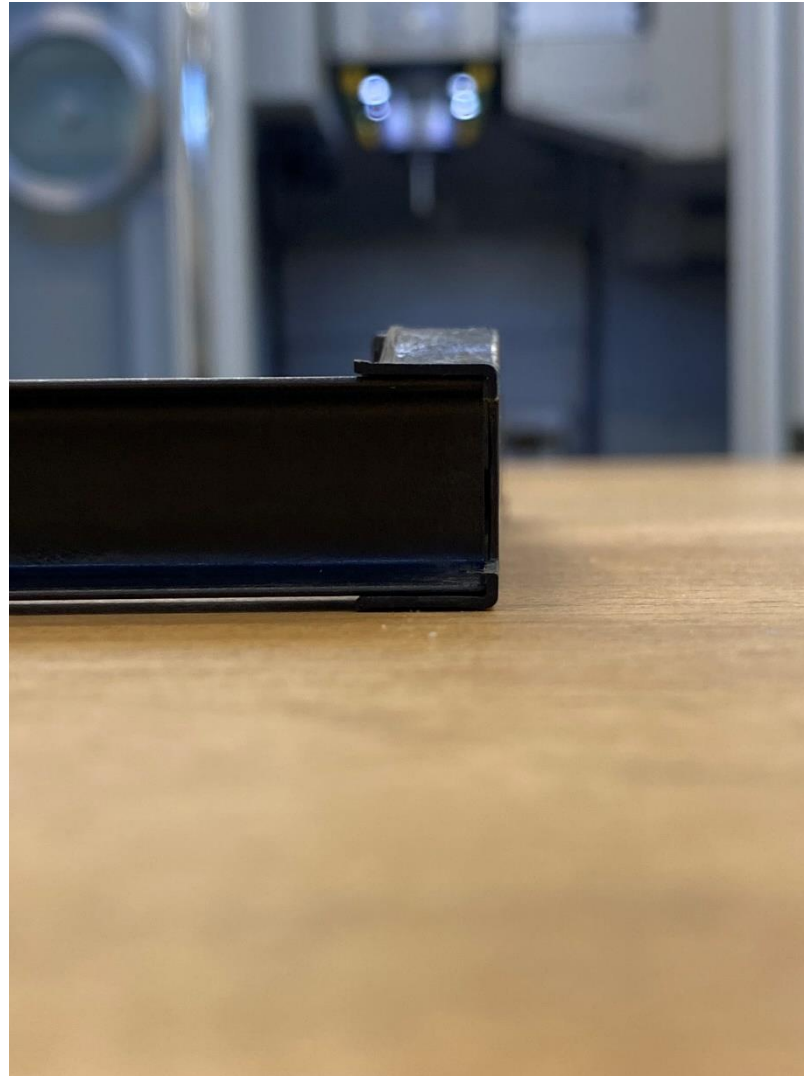


# The mould



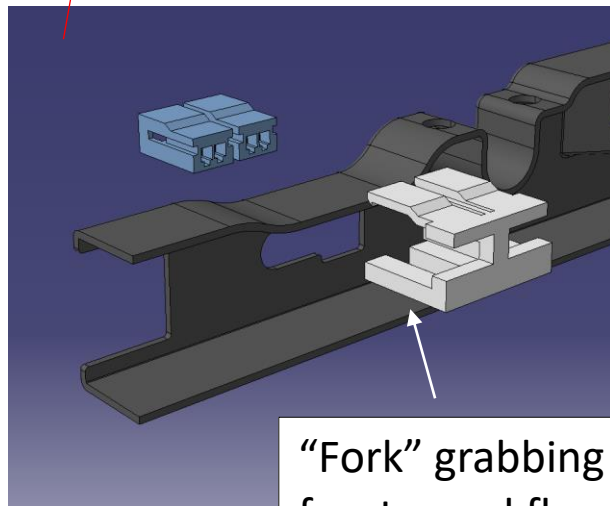
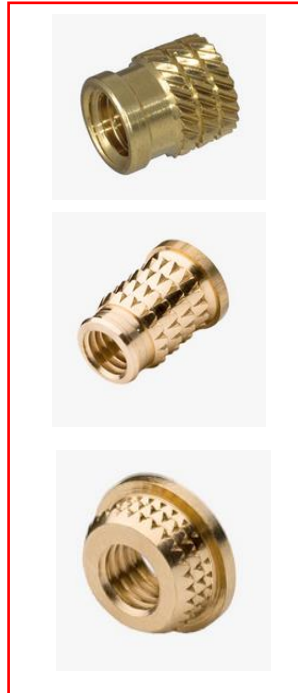
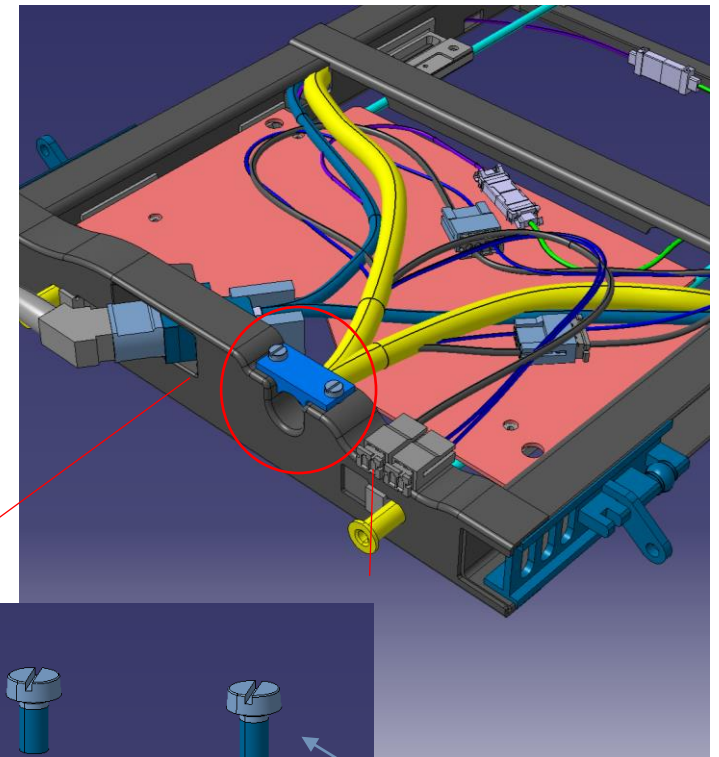
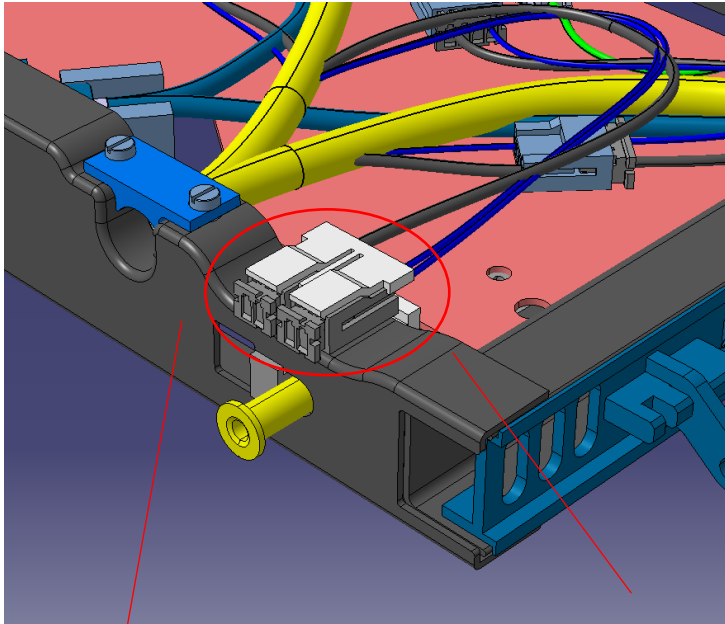


## Front panel fitting to the longitudinal C-profiles

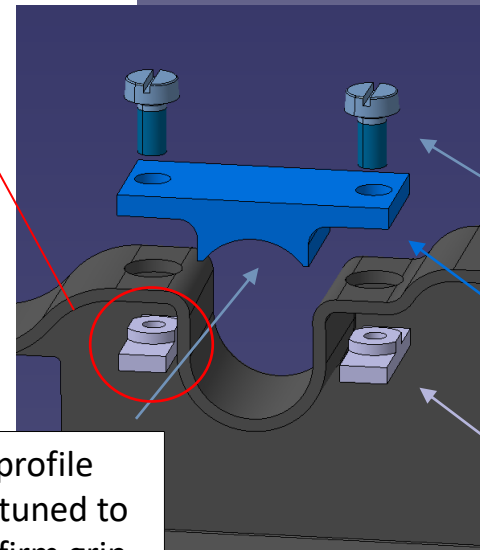




# Front panel service mounting



"Fork" grabbing onto front panel flange



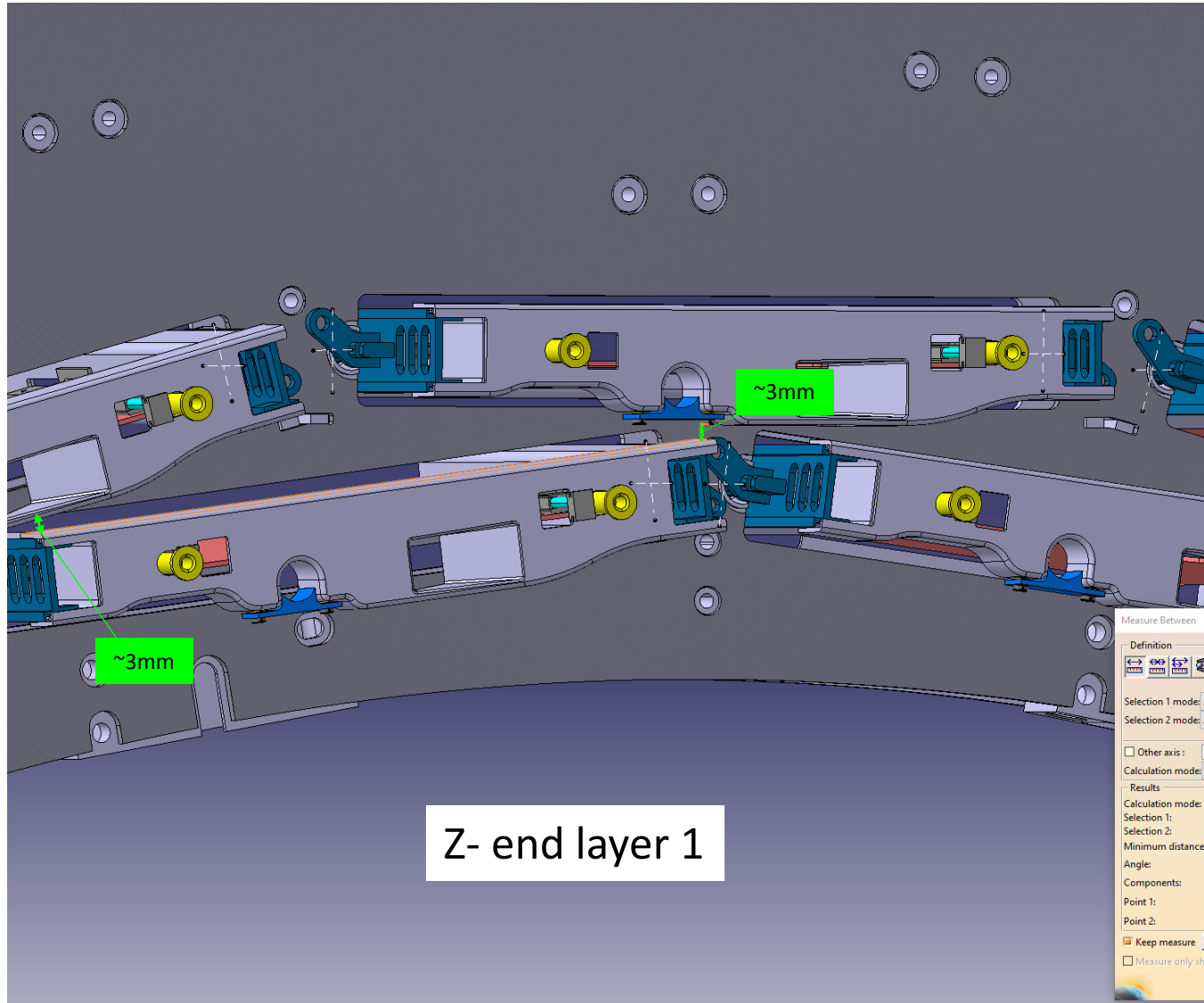
Clamp profile can be tuned to have a firm grip

M2-screws

Clamp

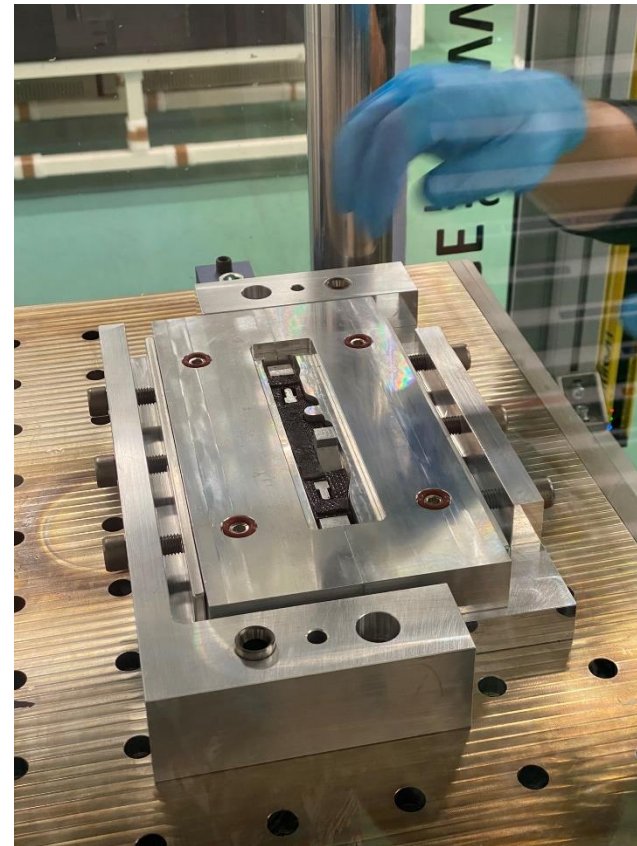
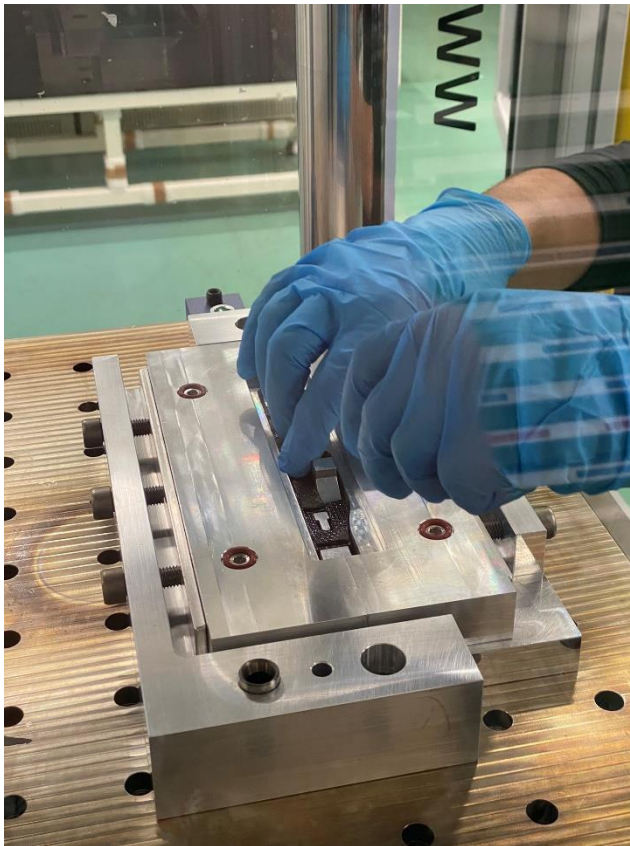
M2-inserts

# Clearances in the wheel



## Setting up the material (epoxy based SMC)

- The pre-cut sheet layers were stuck together, and laying them up to the mould was fast and easy







## Compression (epoxy based SMC)

- The mould was closed almost fully for the 1-minute pre-cure, then closed and pressured fully for the 10-minute pressure cycle



## De-moulding (epoxy based SMC)

- The material flow was very efficient. The resin flowed into the narrow gaps also making more flash to the piece and some clean-up work for the mould, but nothing severe

